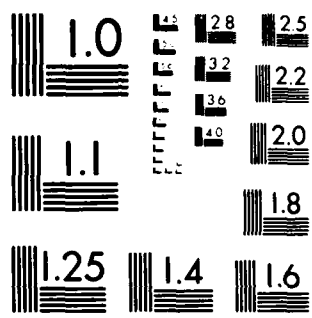END
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THE DESIGN AND DEVELOPMENT OF MILITARY CLOTHING

Part 2.   A Shirt Range Based Upon Anatomical Measurements.

M.G. KING

Approved for public release

APRIL 1982

MAR 22 1983

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83 03 22 030

1a AR No.	1b ESTAB NO	2. DOCUMENT DATE	3. TASK No.
AR-002-400		April 1982	

4. TITLE	5. SECURITY	6. No PAGES
THE DESIGN AND DEVELOPMENT OF MILITARY CLOTHING. Part 2. A Shirt Range Based Upon Anatomical Measurements.	a. Document b. Title c. Abstract	19
		7. No REFS

8. AUTHOR(S)	9. DOWNGRADING INSTRUCTIONS
Dr M. G. King	

10. CORPORATE AUTHOR AND ADDRESS	11. AUTHORITIES (as appropriate)
HQ LOG COMD	A. Sponsor B. Security C. Downgrading D. Approval

12. SECONDARY DISTRIBUTION (of this document)

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13a This document may be ANNOUNCED in catalogues and awareness services available to:

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14. DESCRIPTORS	15. COSATI GROUP
shirts Uniforms.	15050

16. ABSTRACT

From the 1980 survey of the clothing related anatomical measurements of men in the Australian Army (CRAMS), those dimensions related to dress shirts are compared to the dimensions of the current in-service shirt. It is concluded:

a. that the current size roll could be rationalized to provide shirts which fit a greater proportion of the population;

b. that, especially for the larger collar sizes, the in-service shirt range is too large in both waist and chest;

ABSTRACT (CONT'D)

Co' c. that the in-service shirt is too long; and

d. the cuff circumference of the inservice shirt is too large.

Based upon these findings, it is recommended that a modified
set of shirt dimensions should form the basis of a redesigned
shirt, and that this redesigned shirt should be manufactured and
trialled.

IMPRINT

Department of Defence
HQ Logistics Command
Melbourne.
April, 1982.

DOCUMENT SERIES AND NO	COST CODE	TYPE OF REPORT AND PERIOD COVERED

COMPUTER PROGRAMS USED

SPSS: CROSSTABS

SPSS: SCATTERGRAM

ESTAB FILE REF(S)

CONTENTS

THE DESIGN AND DEVELOPMENT OF MILITARY CLOTHING:

Part 2.   A Shirt Range Based Upon Anatomical Measurements.

Dr Michael G. King

Quality Assurance Division
HQ LOG COMD

A SHIRT RANGE BASED UPON ANATOMICAL MEASUREMENTS

Dr M.G. King

AIM

1.   The aim of this report is to present a comparison of the shirt specified by DEF(AUST)5494 with the actual body dimensions of men in the Australian Army - the anatomical information being obtained from analysis of the 1980 CRAMS (Clothing Related Anatomical Measurement Survey) data.

2.   The adequacy of the existing size rolls examined and some changes to the current range of sizes are recommended. Furthermore, the relationships between the various dimensions of the shirt and the distribution of relevant bodily dimensions are considered; where it is possible to improve the fit of the shirt, some alterations to the dimensional details of the shirt range are recommended.

THE SIZE ROLL

3.   The size of a shirt is specified by two values - the sleeve length and the collar size. In the case of the shirt DEF(AUST)5494, 16 collar sizes are offered, covering a range from 32 cm to 47 cm in 1 cm increments; the sleeve length (which is measured from centre back to bottom edge of the cuff) has a range of values from 74 cm to 89 cm, with the increment alternating between 2 and 3 cm for the seven sizes of sleeve length. Of the total 112 possible combinations of shirt and collar sizes, only 38 are currently offered (these are listed in Annex A).

The Demand for Each Size

4.   The CRAMS data provides the neck circumference, and the sleeve length of each of the 21824 subjects measured. By comparison of these values with the parameters defining the shirt size (collar,

and sleeve length) it is possible to estimate the demand for each size, and also the total percentage of the population of the population which is fitted by a particular size roll can be calculated. In the case of the size roll associated with DEF(AUST)5494, the 38 sizes offered provide shirts which fit 54% of the population. The distribution of demand for each size is indicated in Annex A.

5. The following rules were applied to determine the collar and sleeve size required by each man represented by a set of CRAMS measurements:

    a. the neck size (36 cm, for example) corresponds to a shirt with a collar 1 cm greater (37 cm circumference), and it was decided to assign size 36 shirts to those men with necks in the range equal or greater than 35.5 cm to less than 36.5 cm.

    b. for the sleeve sizes, the boundaries between each size were calculated (for example the boundaries for size 81 cm are 80 and 82.5 cm), and the demand for each size was given by the number of men equal to or less than the upper boundary, and greater than the lower boundary.

    c. for the shortest sleeve size, the demand for this size was given by the number of men equal to or less than the upper boundary, because in practice it would be found that the smallest sleeve size would be assigned to all men equal to or less than the size.

SUGGESTED CHANGES TO THE SIZE ROLL

6. Changes to the Collar Sizes. With the current size roll, the collar sizes are incremented in 1 cm steps. This means that whilst a 36 cm collar is designed to fit a 35 cm neck, in practice the difference (or allowance) between the wearer's neck and the shirt collar

may be between 0.5 and 1.5 cm. If it is accepted that this allowance is satisfactory at the smaller end of the scale, then it can be shown (See Annex B) that a larger allowance should be acceptable for larger neck sizes. A larger range in allowance means that the increment between successive sizes can be correspondingly larger. A practical application of this principle is embodied in the recommendation that up to and including collar size 42 cm, size increments should be in 1 cm steps, whilst above collar size 42 cm, increments should be in 1.5 cm steps.

7. **Changes to sleeve length sizes.** As with the collar increments, it is appropriate to use larger increments between the larger sizes, and this is in contrast with the current size roll which employes alternating 2 cm and 3 cm increments throughout the range of sleeve length sizes. Accepting that the 3 cm increment is satisfactory at the small end of the scale, it is suggested that this increment be maintained for the first three sizes.(74 cm, 77 cm, and 80 cm); the next two increments should be 3.5 cm (to 83.5 cm and 87 cm) and, if required, the final increment should be 4 cm (to 91 cm).

8. **The selection of sizes.** The 21284 subjects whose data are listed in the CRAMS data bank were "fitted" by computer with the shirts defined by the new collar and sleeve length sizes. The frequency of demand for each size, based in the results of the computer fitting are shown in Annex C. It is suggested that where the predicted demand for a size exceeded 0.5% of the population (that is, approximately 100, based on the CRAMS sample size), then a shirt should be offered for that size. Based on this criterion, 43 of the cells in the collar : sleeve matrix are indicated as sizes - and these 43 sizes would fit 92.7% of the population.

THE SHAPE OF THE SHIRT

9.   In addition to collar and sleeve dimensions, the
specification for the shirt DEF(AUST)5434 lists seven other measurements:
chest, waist, seat, length, cuff, vent, back width.   Apart from the
sleeve vent, there are CRAMS measurements which correspond to each of
the shirt dimensions and the descriptive statistics of the CRAMS
measurements are presented in Annex D.   The correlation matrix
relating each of the CRAMS dimensions is also given at Annex D.

10.   Annex E lists the nine measurements of each shirt in
the current size roll for the in-service shirt.

CHEST:COLLAR RELATIONSHIP

11.   Reference to the dimensions in Annex E will indicate that
for the in-service shirt the chest dimension increases with increasing
collar size.   Over the range of collar sizes 31 to 35 cm an increment
of 2 cm in chest corresponds to an increment of 1 cm in collar; from
collar size 36 cm to 46 cm the increment in chest is 4 cm for each
1 cm in neck.   This relationship is represented by the solid line
in figure 1.   Also presented in figure 1 is a scattergram plot of a
random 2% sample of the subjects measured in the CRAMS survey (for
the sake of clarity the 21 824 subjects were not plotted on the
scattergram).

12.   From Figure 1 it can be seen that where a man is fitted with
a shirt by collar size, in no case is the shirt too small in the chest.
However the cost of achieving this situation is that in many cases the
shirts may be rather loose in the chest – and this is particularly so
for men with the larger sizes of collar.   Figure 1 shows that
the in-service shirt size range has been designed with the underlying
assumption that men with larger necks (39 cm and above) have increasingly
large chests.   This assumption is not supported by the CRAMS data.

In fact, there is very little systematic increase in chest dimension for men with neck sizes greater than 39 cm.

13.   Suggested Changes.   Considering the limited association between chest and collar dimensions in the larger sizes, it is suggested that the chest size corresponding to a 39 cm collar be maintained for all larger collar sizes.   That is, for collar sizes 39 to 46, the chest should be 120 cm.   Furthermore, from the distribution of measurements in the region below the collar size 35 cm, there appears to be little justification in departing from the 4:1 ratio between chest and collar increments (represented by the continuous line between collar size 35 and 39 cm).   Therefore it is suggested that the 4:1 ratio be continued through the smaller collar sizes.   This would lead to a chest dimension of 88 cm corresponding to the smallest collar size (31 cm).   These suggested modifications are illustrated by the broken line in Figure 1.   It can be seen from this figure that the suggested range of shirts still effectively caters for most of the population: the advantage of better fit is not at the cost of a great number of unfitted subjects.   The suggested modifications are detailed in Annex F.

WAIST:COLLAR RELATIONSHIP

14.   The approach and the results of this analysis closely parallels the investigation of chest:collar relationships.   The waist and collar dimensions of the random 2% sample are illustrated in the scattergram in figure 2.   Also represented in this figure, by a solid line, is the relationship between waist and collar in the in-service shirt.   It can be seen from this sample that in some instances a man may be fitted by collar size, but he may find that the shirt is too tight in the waist region - and this is more frequently the case in the middle range of collar sizes.   For the larger collar sizes, the shirts are unnecessarily voluminous in the waist.

15. **Suggested figures.** As with the chest:collar data, there is little evidence of the need for systematic increase in waist size corresponding to increasing collar size beyond a collar size of 39 cm. It is therefore suggested that a constant waist dimension of 110 cm be adopted for all shirts of collar size 39 cm and above. For collar sizes 31 to 38 cm it is suggested that a ratio size should be accompanied by an increment of 5 cm in the waist of the shirt, starting from a waist of 70 cm with the smallest collar size of 31 cm. These modifications are represented by the broken line in figure 2. The suggested modifications are detailed in Annex B.

THE CUFF

16. Tailoring conventions suggest that an allowance of approximately 7 cm (the excess of the circumference of shirt cuff over the wrist circumference) is acceptable. The current specification has cuffs ranging from 21 cm to 28 cm — the increase being associated with increasing collar size. From the CRAMS data, the statistical data relating to wrist and collar are given by the linear regression equation:

$$\text{wrist} = 0.19 \text{ collar} + 10$$

17. From the above relationships, for each collar size the 99th centile (maximum) wrist circumference and the average wrist circumference were calculated for each collar size. Bearing in mind the target of an average 7 cm allowance, and the practical need for whole number dimensions where possible, the cuff dimensions incorporated in the draft specification, Annex E, were computed. In no case does the allowance for the 99th centile man fall below the limit of 5 cm.

LENGTH

18.   Although the current shirt range features lengths from 76 to 88 cm (the increase being associated with increasing collar) the CRAMS data suggests that these shirts are too long.   The mean man's body length is 70 cm, and the standard deviation is 3.5 cm.   The relationship between bodylength and the two defining variables (collar and sleeve length) is given by the multiple regression equation:

$$length = 0.513 \text{ collar} + 0.232 \text{ sleeve} + 31$$

with the multiple regression coefficient $R = 0.49$

19.   From the residual variance (after the application of the above regression equation), the 99th centile length was calculated for each sleeve and collar combination.   These maximum values were rounded to the nearest 5 cm increment (in keeping with standard tailoring practice), and the recommended shirt lengths listed in Annex E are equal to the rounded 99th centile body length for that size.

CONCLUSION

20.   Consideration of the current size roll leads to the following conclusions:

    a.   the current size roll affords a good fit to 54% of the population, with 38 sizes being specified;

    b.   a rationalization to the increments between successive collar sizes, and between successive sleeve sizes is justified, with larger increments being specified between the larger sizes;

    c.   by adopting a rationalized size roll structure, and selecting sizes in high demand, it is possible to provide shirts to fit approximately 93% of the Australian Army with 43 sizes.

3. each of the 13 specified sizes has a predicted
    demand of at least 0.5% of the population.

4. The in-service shirt specified by DEF(AUST)5494 has been
compared with data from CRANC. With regard to the ratios of chest
to collar, and waist to collar, it is concluded that:

      a. for the larger sizes (greater than collar size 39)
the shirts are too large in both chest and waist;

      b. the adoption of minor modifications to the scale of
ratios between waist:collar and chest:collar should
result in a better fit for a greater proportion of
the population;

      c. the length of in-service shirt is too great, in a
number of sizes, and a rationalized recommendation
provides a shirt length which will fit the 99th
centile man for each size;

      d. the cuff circumference has been altered to provide a
satisfactory allowance (average 7 cm, minimum 5 cm)
for each size.

RECOMMENDATIONS

22.   That the specifications of the Shirt, Mens, Polyester/Cotton
described by DEF(AUST) 5494 be re-examined by tailoring and design
professionals with a view to modifying the design parameters.

23.   That the suggestions detailed in Annex F be considered by
tailoring and design experts and - if compatible with tailoring and
design conventions - these suggestions should form the basis of
modifications to the design parameters of the Shirt.

SCATTERGRAM OF COTTON/POLY SHIRT (DEF.AUST 5494)   FIGURE 1
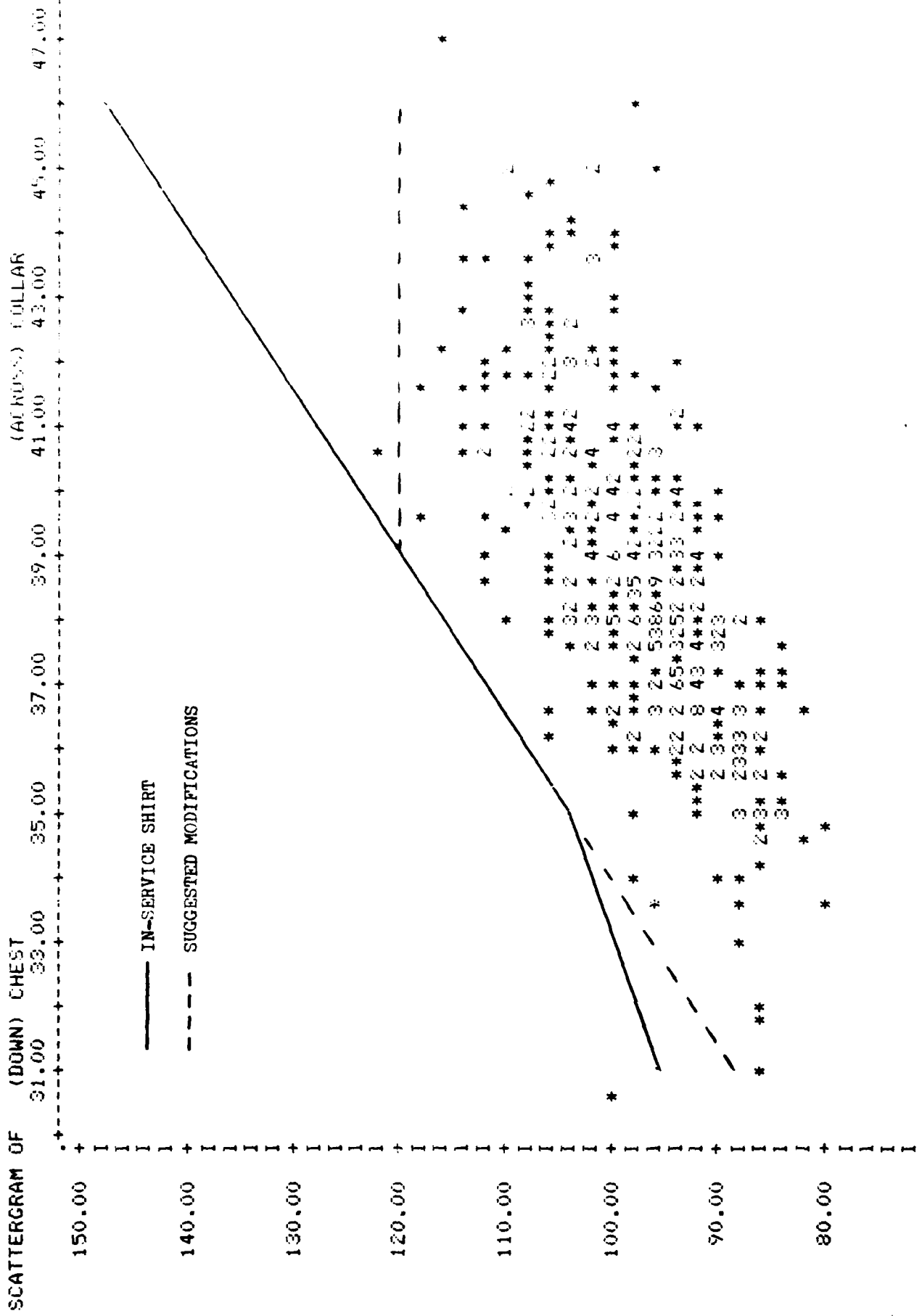
SCATTERGRAM OF COTTON/POLY SHIRT (DEF.AUST 5494)   FIGURE 2
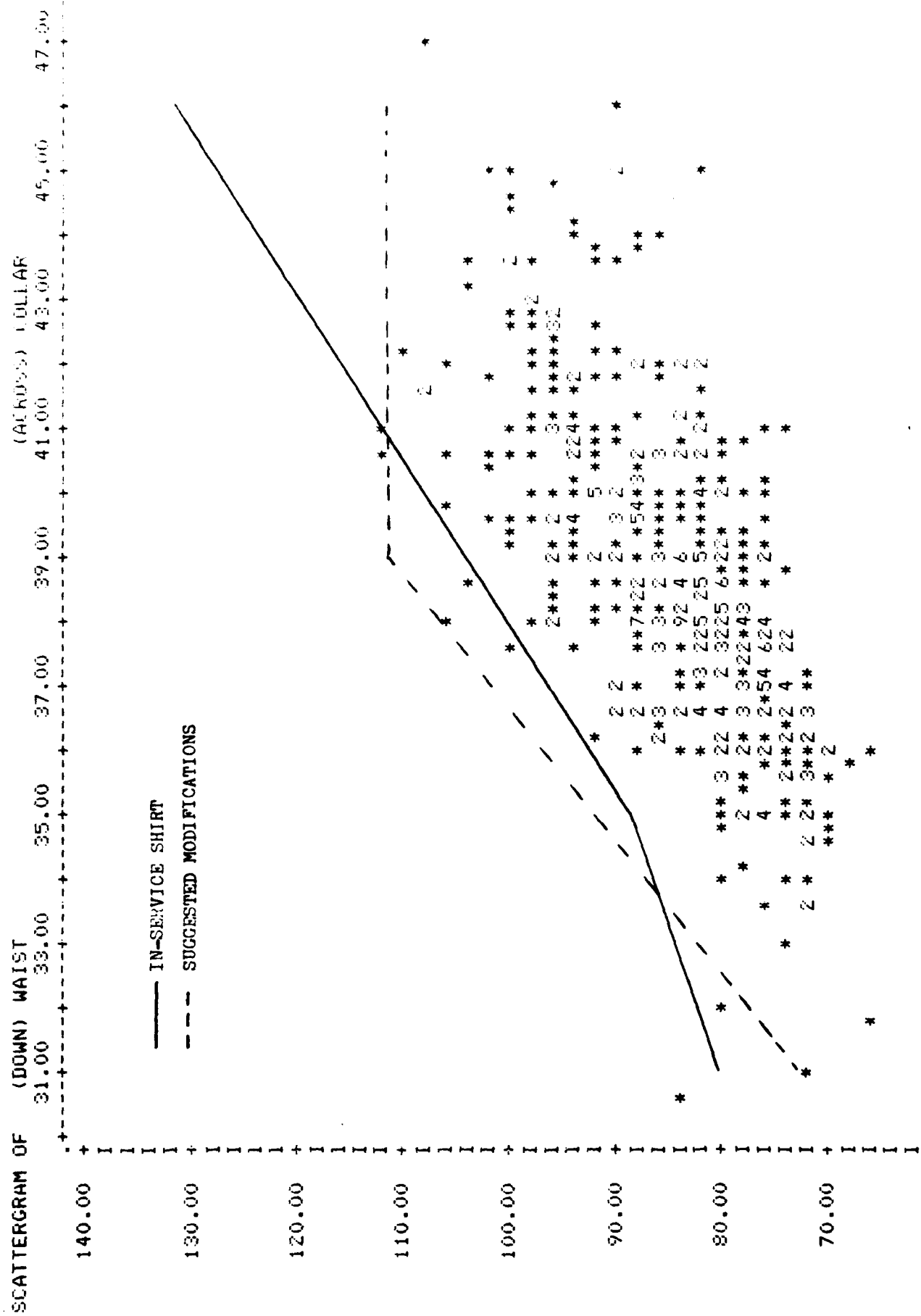
MATRIX OF SIZES AND DEMAND FOR CURRENT SHIRT

sizes offered indicated by heavy outline

SLEEVE LENGTH, CM

NECK	74	76	79	81	84	86	89	ROW TOTAL
31	25	8	0	2	3	2	0	40
32	46	10	5	3	0	1	2	67
33	42	25	25	8	3	0	0	103
34	75	81	83	51	22	6	2	320
35	166	191	200	185	74	24	8	848
36	265	384	503	329	197	68	26	1772
37	330	489	767	628	337	153	58	2762
38	365	589	941	855	495	253	100	3598
39	301	555	935	899	603	288	137	3718
40	214	438	800	807	536	258	123	3176
41	139	279	531	570	428	208	104	2261
42	62	130	305	333	265	150	84	1329
43	34	84	162	189	158	90	56	773
44	29	47	80	117	84	45	42	444
45	6	15	37	50	44	20	10	182
46	4	3	10	14	18	7	9	65
COLUMN TOTAL	2103	3328	5384	5040	3267	1573	743	21458
	9.8	15.5	25.1	23.5	15.2	7.3	3.6	100.0

THE VARIATION IN CIRCUMFERENTIAL ALLOWANCE

FOR A RANGE OF COLLAR SIZES

1.   The allowance of a shirt collar is the difference
between collar circumference and neck circumference.   If the
collar is pulled tight as illustrated
in the accompanying diagram, figure 1,
then the allowance is given by:

$$D/2 = r \tan\phi - r\phi \quad (1)$$

where D is collar – neck

and ϕ is the angle shown in

figure 1.

figure 1

2.   If the concept of fit/non-fit is defined by a
limiting value of the angle θ which is formed by the excess
material when the collar is pulled tight, then a maximum
and a minimum value for ϕ can be calculated for any neck size.
In particular, if the maximum allowance which is acceptable
for a 32 cm circumference neck is 1.5 cm, then:

$$1.5 = 32 (\tan\phi - \phi)/\pi$$

$$\text{thus } (\tan\phi - \phi)/\pi = 0.0469.$$

From this value the maximum allowances may be obtained for other
neck sizes;   similarly the minimum tolerance values may be
calculated using the criterion of 0.5 cm for a 32 cm neck.
The range of maximum and minimum allowances are listed in Table 1
of this Annex.

3.   An allowance of 1.5 cm maximum corresponds to collar increments of 1 cm, whilst a 2 cm maximum allowance corresponds to 1.5 cm collar increments (assuming that a 0.5 cm minimum allowance is used).   In keeping with the goal of avoiding fractional measurements where possible, it was decided to recommend that for neck sizes up to 41 cm (that is, collar sizes of 42 cm) a 1 cm collar increment should be used, whilst for the larger sizes a 1.5 cm increment should be adopted.

Table 1

The Range of Maximum and Minimum Allowance

neck	maximum	minimum
32	1.5	.4
34	1.6	.5
36	1.7	.5
38	1.8	.5
40	1.9	.6
42	2.0	.6
44	2.1	.6
46	2.2	.6

MATRIX OF SIZES AND DEMAND FOR RECOMMENDED SHIRT

	SHIRT SLEEVE LENGTH IN CM						
COLLAR	74	77	80	83.5	87	91	
31	5	2	3	1	1	0	1
32	25	8	1	3	3	0	40
33	47	11	5	1	3	0	67
34	45	31	20	7	0	0	10
35	81	104	89	36	7	1	
36	178	240	258	135	39	4	848
37	291	492	542	333	103	12	1772
38	358	702	888	569	218	34	2707
39	394	811	1167	831	325	70	3600
40	335	745	1170	975	425	74	3777
41	239	599	1016	885	375	71	
42	148	375	697	654	315	57	2270
43.5	91	261	494	508	276	71	1701
45.0	47	118	223	281	146	42	857
46.5	8	28	55	79	32	11	

heavy outline indicates 43 recommended sizes
to fit 20231 men, that is, 97% of all subjects.

ZOLL

STATISTICS OF SHIRT-RELATED VARIABLES

TAKEN FROM IR IS DATA

	mean, cm	standard deviation, cm.	number
collar	38.8	2.42	21785
chest	97.7	7.18	21794
waist	84.24	8.59	21803
seat	96.61	6.23	21777
wrist	17.57	0.896	21794
sleeve	80.24	4.09	21681
body length (cervical height minus inside leg)	70.02	3.51	21440

CORRELATION MATRIX

	chest	waist	seat	body	sleeve	wrist
collar	.677	.669	.610	.422	.246	.509
chest		.812	.781	.467	.296	.525
waist			.816	.396	.238	.477
seat				.525	.301	.527
body					.351	.406
sleeve						.379

CH TABLE OF ... POLY ...TON/COTTON
A L... ... Di... In ...

LONG AND SHORT SLEEVES

Size (neck and sleeve sizes)	Length of collar from eye of buttonhole to centre of button	Girth at base of armhole when buttoned	Girth at waist when buttoned	Girth around the shirt at side vent	Length of back and front from top of shirt at side of collar	Sleeve length from centre back to bottom edge of cuff	Cuff from eye of buttonhole to centre of button	Sleeve vent opening from tack to bottom of cuff	Back width at yoke	Length from centre crown to turn-up	Width of sleeve at turn-up
31 - 74	32	96	80	96	78	74	21	21	36	21	16.5
32 - 76	33	98	82	98	78	76	21	21	37	21	
33 - 79	34	100	84	100	80	79	22	21		33	17
34 - 81	35	102	86	102	80	81	23	21	39	33	17
35 - 81	36	104	88	104	82	81	23	21	40	22	17.5
36 - 81	37	106	92	108	82	81	23	21	41	22	18
37 - 79 / 81	38	112	96	112	84	79 / 81	25	22	42	22	18.5
38 - 81 / 84 / 86	39	116	100	116	84	81 / 84 / 86	25	22	43	22	19
39 - 79 / 81 / 84 / 86 / 89	40	120	104	120	84	79 / 81 / 84 / 86 / 89	25	22	44	22	19.5
40 - 79 / 81 / 84 / 86 / 89	41	124	108	124	84	79 / 81 / 84 / 86 / 89	25	22	45	24	20

Size (Neck and Sleeve sizes)	Length of collar from eye of buttonhole to centre of button	LONG AND SHORT SLEEVES								SHORT SLEEVES	
		Girth at base of armhole when buttoned	Girth at waist when buttoned	Girth around the shirt at side vent	Length of back and front from top of shirt at side of collar	Sleeve length from centre back to bottom edge of cuff	Cuff from eye of button-hole to centre of button	Sleeve vent opening from tack to bottom of cuff	Back width at yoke	Length from centre crown to turn-up	Width of sleeve at turn-up
41 - 81 84 86 89	42	128	112	128	86	81 84 86 89	26	22	46	24	20.5
42 - 81 84 86 89	43	132	116	132	86	81 84 86 89	26	22	47	24	21
43 - 84 86 89	44	136	120	136	86	84 86 89	27	23	48	25	21.5
44 - 84 86 89	45	140	124	140	88	84 86 89	27	23	49	25	22
45 - 86 89	46	144	128	144	88	86 89	28	23	50	25	22.5
46 - 89	47	148	132	145	86		28	23	51	25	23

SIZE chest and sleeve	COLLAR length of collar from buttonhole to centre of button	CHEST girth at base of armhole buttoned	WAIST girth at waist buttoned	SEAT girth at side vent	LENGTH length of back and front from top of shirt	SLEEVE sleeve length from centre back to bottom edge of cuff	CUFF cuff from eye of buttonhole to centre of button	VENT sleeve vent: tack to bottom of cuff
34-77	35	100	87	100	75	77	23	19
35-74 35-77 35-80 35-83	36	104	92	104	75 75 75 75	74 77 80 83.5	23	19
36-74 36-77 36-80 36-83 36-87	37	108	97	108	75 75 75 75 75	74 77 80 83.5 87	23	19
37-74 37-77 37-80 37-83 37-87	38	112	102	112	75 75 75 75 75	74 77 80 83.5 87	24	19
38-74 38-77 38-80 38-83 38-87	39	116	107	116	75 75 75 75 75	74 77 80 83.5 87	24	19
39-74 39-77 39-80 39-83 39-87	40	120	112	120	75 75 75 75 80	74 77 80 83.5 87	24	19
40-74 40-77 40-80 40-83 40-87	41	120	112	120	75 75 75 80 80	74 77 80 83.5 87	25	19
41-74 41-77 41-80 41-83 41-87	42	120	112	120	75 75 75 80 80	74 77 80 83.5 87	25	19
43-77 43-80 43-83 43-87	43.5	120	112	120	80 80 90 80	77 80 83.5 87	25	19
44-77 44-80 44-83 44-87	45	120	112	120	80 80 80 80	77 80 83.5 87	25	19

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